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POWER DISTRIBUTION SYSTEM HAVING REDUNDANT MIXED SOURCES AND METHOD

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POWER DISTRIBUTION SYSTEM HAVING REDUNDANT MIXED SOURCES AND METHOD

BACKGROUND OF THE INVENTION

[1] The present invention is generally directed to a power system for providing power to a plurality of loads, such as, a computer system. The present invention is more particularly directed to such a power system which is capable of being sourced by redundant sources to provide flexibility and reliability.

[2] There are many applications where a power system must provide reliable power to the system which it powers. A computer system is one example.

[3] Previous computer systems were generally provided with their own AC input power supplies. These AC "front-end" supplies produced positive DC voltage outputs. From these positive DC voltage outputs, power subsystems produced mid- and low-rail voltages. When these computer systems needed to be adapted for use in the Telecom industry, power system redesign was required due to the -48 V DC voltages available to power the computer system. In the end, the computer system power supplies for the Telecom industry were difficult to design, required higher component density, were more expensive, and required long lead-times. To provide power supply redundancy for reliability, two similar supplies were generally employed.

[4] It is generally desirable for computer systems in general, and those used in the Telecom industry specifically, to be continuously powered. Telecom systems utilized in the Telecom industry are generally rack mounted as is the telephone equipment. The racks are generally standardized to accept computer equipment, such as computer servers, hereinafter referred to as a load, of a preset width of, for example, 19 inches, and a whole number of height units referred to as "U's".

[5] Once a rack is configured with its loads, it is then necessary to match it with a rack of power sources. It would be desirable to be able to configure the power distribution system so that all of the loads would remain fully powered at all times. This would require redundancy in power sources. Unfortunately, redundancy of this

kind has been difficult to obtain in the past. This is due to the fact that loads could not use the -48 V DC directly, commonly available in the Telecom industry, but instead, each had its own power supply to provide required DC voltages from AC inputs. As a result, power distribution systems incorporating loads, such as computer equipment, for use in the Telecom industry, required power input redesign to enable the equipment to be powered directly from the standard DC voltage available in the Telecom industry environment. One such power distribution system directed to this end which provides full power source redundancy is disclosed, for example, in copending U.S. Patent Application Serial No. _______ (Attorney Docket No. 200209624-1 (1964-33-3)), filed _______, and titled REDUNDANT INPUT POWER SYSTEM, which application is incorporated herein by reference. The system disclosed in this application permits loads, such as computer equipment, to be standardized for receipt within a rack of preset width and having a height equal to a whole number of height units. This also permits standardization of power sources. For example, six AC power supply providing 1,000 watts each of DC power at -48 V DC may have a rack height of 3U. Similarly, multiple standard 2,000 watt, -48 V DC battery supply feeds from the telecom industry's bus bar infrastructure are normally available above the racks. Both the AC sources and DC sources may provide the same DC output voltage of, for example, -48 V DC.

[6] When configuring a power distribution system, once a rack of loads is configured, it is then necessary to configure the power sources for those loads. As previously mentioned, it is desirable to so configure the power sources such that the sources are interconnected with the loads in a manner which provides complete and continuous power to each of the loads notwithstanding failure of one of the power sources. This provides the desired redundancy. Further, it would be most desirable to so configure the power distribution system such that the number of power sources is reduced to a minimum while providing the desired redundancy. The present invention addresses these issues and requirements.

SUMMARY OF THE INVENTION

[7] In one embodiment, a power distribution system is provided that includes a bank of sources including a first group of sources and a second group of

sources, a bank of loads, and an interconnect arrangement including a plurality of interconnects. The interconnects connect each load to one or more sources of both the first and second groups of sources so as to be fully powered by sources of both the first and second groups of sources and such that if any one source or all sources of one of the groups of sources fails, all of the loads remain fully powered.

[8] According to another embodiment, the invention further provides a method of distributing power to a bank of loads. The method includes the steps of providing a bank of sources including a first group of sources and a second group of sources and providing a plurality of interconnects. The method further includes the steps of connecting, with the interconnects, each load through one or more sources of both the first and second groups of sources to enable sources of both the first and second groups of sources to fully power the loads and such that any one or more of the sources of one of the groups of sources fails, all of the loads remain fully powered.

BRIEF DESCRIPTION OF THE DRAWINGS

[9] These and various other features as well as advantages of the present invention will be apparent from a reading of the following detailed description and a review of the associated drawings, in the several figures of which like reference numerals identify identical elements, and wherein:

[10] **FIG. 1** illustrates a first embodiment of the present invention wherein the power distribution system thereshown includes twelve 500 watt loads, six 1,000 watt AC sources, and three 2,000 watt DC sources;

[11] **FIG. 2** illustrates a second embodiment of the present invention wherein the power distribution system thereshown includes six 1,000 watt loads, six 1,000 watt AC sources, and three 2,000 watt DC sources;

[12] **FIG. 3** illustrates a further embodiment of the present invention wherein the power distribution system thereshown includes three 2,000 watt loads, six 1,000 watt AC sources, and three 2,000 watt DC sources;

[13] **FIG. 4** illustrates a further embodiment of the present invention wherein the power distribution system thereshown includes two 3,000 watt loads, six 1,000 watt AC sources, and three 2,000 watt DC sources; and

[14] **FIG. 5** illustrates a still further embodiment of the present invention wherein the power distribution system thereshown includes one 6,000 watt load, six 1,000 watt AC sources, and three 2,000 watt DC sources.

DESCRIPTION OF THE INVENTION

[15] In the following detailed description of exemplary embodiments of the invention, reference is made to the accompanying drawings, which form a part thereof. The detailed description and the drawings illustrate specific exemplary embodiments by which the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention. It is understood that other embodiments may be utilized, and other changes may be made, without departing from the spirit or scope of the present invention. The following detailed description is therefore not to be taken in a limiting sense, and the scope of the present invention is defined by the appended claims.

[16] **FIG. 1** illustrates a first power distribution system ***10*** embodying the present invention. The power distribution ***10*** includes a bank of sources ***12***, a bank of loads ***14***, and an interconnect arrangement ***16***.

[17] The bank of sources ***12*** illustrated in **FIG. 1** and which is replicated in the remaining **FIGS. 2-5** includes a first group of sources including sources ***20-25***. Each of the first group of sources ***20-25*** may be an AC source which converts an AC input voltage to a DC output voltage to be utilized by the loads of the power distribution system. In accordance with this and the other described embodiments of the present invention, the first group of sources ***20-25*** each have a 1,000 watt capacity. Of course, the first group of sources may have other capacities without departing from the present invention. Where the power distribution system ***10*** is to be employed in a Telecom facility, the DC output voltage of each of the first group of sources ***20-25*** is preferably -48 V DC.

[18] The bank ***12*** of power sources further includes a second group of sources including sources ***26***, ***27***, and ***28***. Each of the second groups of sources is preferably a DC source, derived from, for example, battery power. Each of the second group of sources ***26-28*** has a capacity of 2,000 watts and, wherein the power distribution system ***10*** is to be employed in a Telecom facility, preferably provides a -48 V DC output. Of course, the output voltages and capacities of the second group of sources may vary without departing from the invention.

[19] The bank of loads includes a plurality of loads, and more specifically, loads ***30-41***. Each of the loads ***30-41*** may be computer related equipment such as computer servers or other equipment which may be used, for example, in a Telecom facility.

[20] It will be noted that in this embodiment, and the other embodiments to be described hereinafter, the capacities of the sources and the power consumption of the loads are in 500 watt multiples. However, equipment exhibiting multiples other than 500 watts may be employed without departing from the present invention.

[21] The interconnect arrangement ***16*** includes a plurality of interconnects. The interconnects connect each one of loads ***30-41*** to one or more of the sources of both the first group of sources ***20-25*** and the second group of sources ***26-28*** so as to be fully powered by sources of both the first and second groups of sources and such that if any one source or all sources of one of the groups of sources fails, all of the loads remain fully powered.

[22] The above is accomplished in accordance with this embodiment by dividing the power distribution system ***10*** into three subsystems ***42***, ***44***, and ***46***. Each of the subsystems ***42***, ***44***, and ***46*** includes two of the 1,000 watt AC sources, one 2,000 watt DC source, and four of the 500 watt loads. In terms of the consumption of the capacity multiple, if 500 equals X, each subsystem therefore includes four X watt loads, two 2X watt first group sources, and one 4X watt second group source. The interconnect arrangement ***16*** connects the loads to the sources such that, for each subsystem, two of the X watt loads are connected to a common one of a two X watt first group sources, another two of the loads are connected to another one of the two X watt first group sources, and all of the X watt loads are connected to the 4X watt

second group source. Hence, as for example, the subsystem ***42*** includes 500 watt loads ***30***, ***31***, ***32***, and ***33***, 1,000 watt first group sources ***20*** and ***21***, and 2,000 watt second group source ***26***. Loads ***30*** and ***31*** are connected in common to source ***20***, loads ***32*** and ***33*** are coupled in common to source ***21***, and all of the 500 watt loads ***30-33*** are connected to the 2,000 watt source ***26***. The sources and loads of subsystems ***44*** and ***46*** are similarly connected in this same manner.

[23] As can been seen from the above, the interconnects connect the loads ***30-41*** to the sources ***20-28*** to provide redundant sourcing. More particularly, the loads are connected to the sources in such a way that each load is fully powered by sources of both the AC sources and DC sources and such that if any one or all of the AC sources or any one or all of the DC sources fails, all of the loads remain fully powered.

[24] The redundant connection of each of the loads ***30-41*** may be accomplished as, for example, described in copending U.S. Application Serial No. ___________ (Attorney Docket No. 200209624-1 (1964-33-3)), filed February 5, 2004, for REDUNDANT INPUT POWER SYSTEM, which application is assigned to the assignee of the present invention and incorporated herein by reference. As will be noted from that application, redundant connection of a load to various sources is provided by a power OR circuit.

[25] Referring now to **FIG. 2**, it illustrates a further embodiment of the present invention. The power distribution system ***50*** of **FIG. 2** includes the bank ***12*** of sources as previously described, a bank ***52*** of loads and an interconnect arrangement ***59***.

[26] The bank ***12*** of sources includes the first group of 1,000 watt AC sources ***20-25*** and the second group of 2,000 watt DC sources ***26-28***. The bank ***52*** of loads includes loads ***53-58***. Each of the loads ***53-58*** has a power consumption rating of 1,000 watts.

[27] Again, in accordance with the present invention, the interconnect arrangement ***59*** connects the loads to the sources such that each load is connected to one or more sources of both the first and second groups of sources so as to be fully powered by sources of both the first and second groups of sources and such

that if any one source or all sources of one of the groups of sources fails, all of the loads remain fully powered. To that end, the power distribution system ***50*** may be divided into subsystems ***62***, ***64***, and ***66***. Each subsystem includes two 2X watt loads, two 2X watt first group sources, and one 4X watt second group source, wherein X is equal to 500. For each subsystem, each of the 2X watt loads is connected to a different one of the 2X watt first group sources and to the 4X watt second group source. Hence, with respect to subsystem ***62***, for example, loads ***53*** and ***54*** are connected to different ones of first group sources ***20*** and ***21*** and to the 2,000 watt second group source ***26***. Subsystems ***64*** and ***66*** are similarly connected.

[28] Hence, the power distribution system of **FIG. 2** provides redundancy and reliability should any one or all of the AC sources or any one or all of the DC sources fail. In this event, all of the loads ***53-58*** will remain fully powered.

[29] Referring now to **FIG. 3**, it illustrates a still further embodiment of the present invention. The power distribution system ***70*** thereshown includes the bank ***12*** of power sources, a bank ***72*** of loads, and an interconnect arrangement ***74***. The bank ***12*** of sources is as previously described. The bank ***72*** of loads includes 2,000 watt loads ***75***, ***76***, and ***77***. Again, the power system ***70*** may be divided into subsystems ***82***, ***84***, and ***86*** wherein each subsystem includes two 2X watt first group sources, one 4X watt second group source, and a 4X watt load. The interconnect arrangement ***74*** connects the sources and loads of each subsystem so that for each subsystem, the 4X watt load is connected to the 2X watt first group sources and to the 4X watt second group source. Hence, as with subsystem ***82***, the 2,000 watt load is coupled to the 1,000 watt AC first group sources ***20*** and ***21*** and to the 2,000 watt DC second group source ***26***. The other subsystems ***84*** and ***86*** are similarly connected. As a result, if any one or all of the AC sources fails or if any one or all of the DC sources fails, each of the loads ***75***, ***76***, and ***77*** will remain fully powered.

[30] Referring now to **FIG. 4**, it illustrates a still further embodiment of the present invention. Here, the power distribution system ***90*** includes the bank ***12*** of sources, a bank ***92*** of loads, and an interconnect arrangement ***94***. The bank ***12*** of sources is as previously described. The bank ***92*** of loads includes 3,000 watt loads ***95*** and ***96***. Hence, the power distribution system ***90*** includes 2X watt (1,000 watt)

first group AC sources ***20-25***, 4X watt (2,000 watt) second group DC sources ***26***, ***27***, and ***28***, and 6X watt (3,000 watt) loads ***95*** and ***96***. The interconnect arrangement ***94*** connects load ***95*** to each of sources ***20***, ***21***, ***22***, ***26***, and ***27*** and load ***96*** to each of sources ***23***, ***24***, ***25***, ***27***, and ***28***. Hence, each of the loads ***95*** and ***96*** is connected to a common one and a unique one of the sources ***26***, ***27***, and ***28***, and to a unique three source subgroup of sources ***20-25***. In this manner, should any one or all of the AC sources or any one or all of the DC sources fail, both loads ***95*** and ***96*** will remain fully powered.

[31] Referring now to **FIG. 5**, it illustrates a power distribution system ***100*** which also embodies the present invention. The system ***100*** includes the bank ***12*** of sources, a 6,000 watt load ***102***, and an interconnect arrangement ***104***. The interconnect arrangement ***104*** couples the load ***102*** to each of the sources of the bank ***12*** of sources. As will be noted from **FIG. 5**, if any one of the AC sources or any one of the DC sources should fail, the load ***102*** will remain fully powered.

[32] Although the present invention has been described in considerable detail with reference to certain preferred embodiments, other embodiments are possible. Therefore, the spirit or scope of the appended claims should not be limited to the description of the embodiments contained herein. It is intended that the invention resides in the claims.